Extreme Heat and Air Quality

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Photo of London: New York Times (2/17/2017)

Motivation

- Understanding and forecasting air quality is a national and global concern.
- The number of people exposed to extreme heat at least once every five years will double under a 2°C scenario relative to a 1.5°C scenario (IPCC).
- Warmer days and extreme heat events will stress populations by exacerbating poor air quality resulting from increased near-surface ozone (O_3) and particulate matter (PM).
- NOAA has the mandate and the capability to understand how the Earth system will change in a warmer world.
- The challenge for OAR’s Labs and Programs, including CPO/ESSM, is to understand changing atmospheric composition, emissions and state conditions, in order to properly characterize and project changes in air quality resulting from extreme heat.

US air quality improved significantly beginning in the 1970’s due to the Clean Air Act and subsequent regulations. But recent monitoring data suggest a reversal of national pollution trends. And many Americans still live in areas that don’t meet current regulatory standards for O_3 and PM.

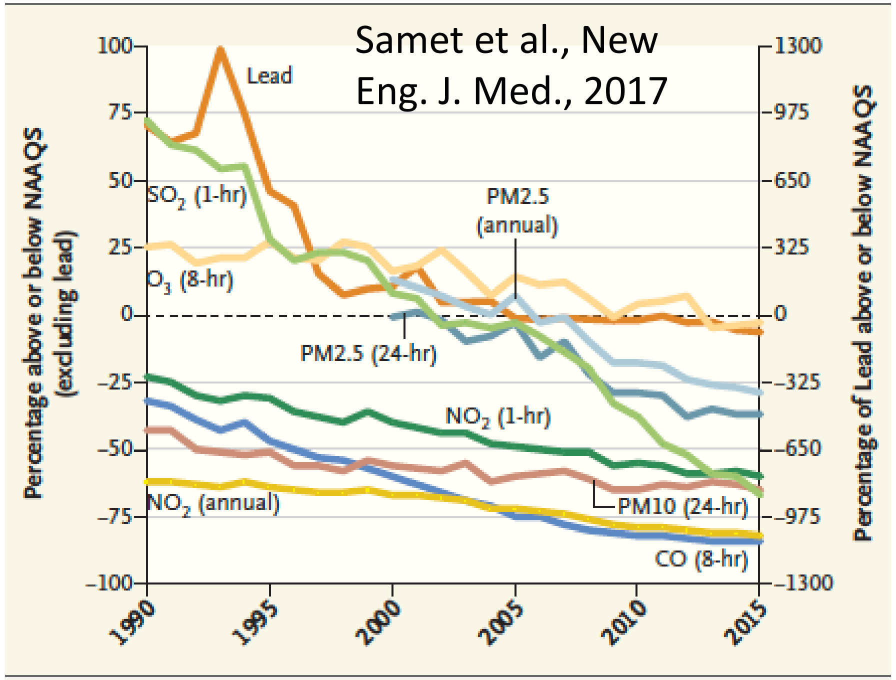
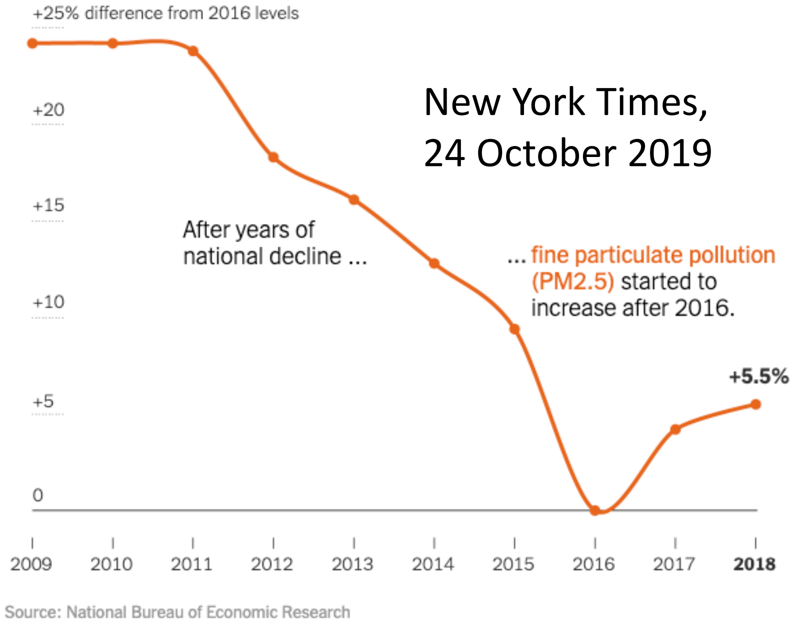
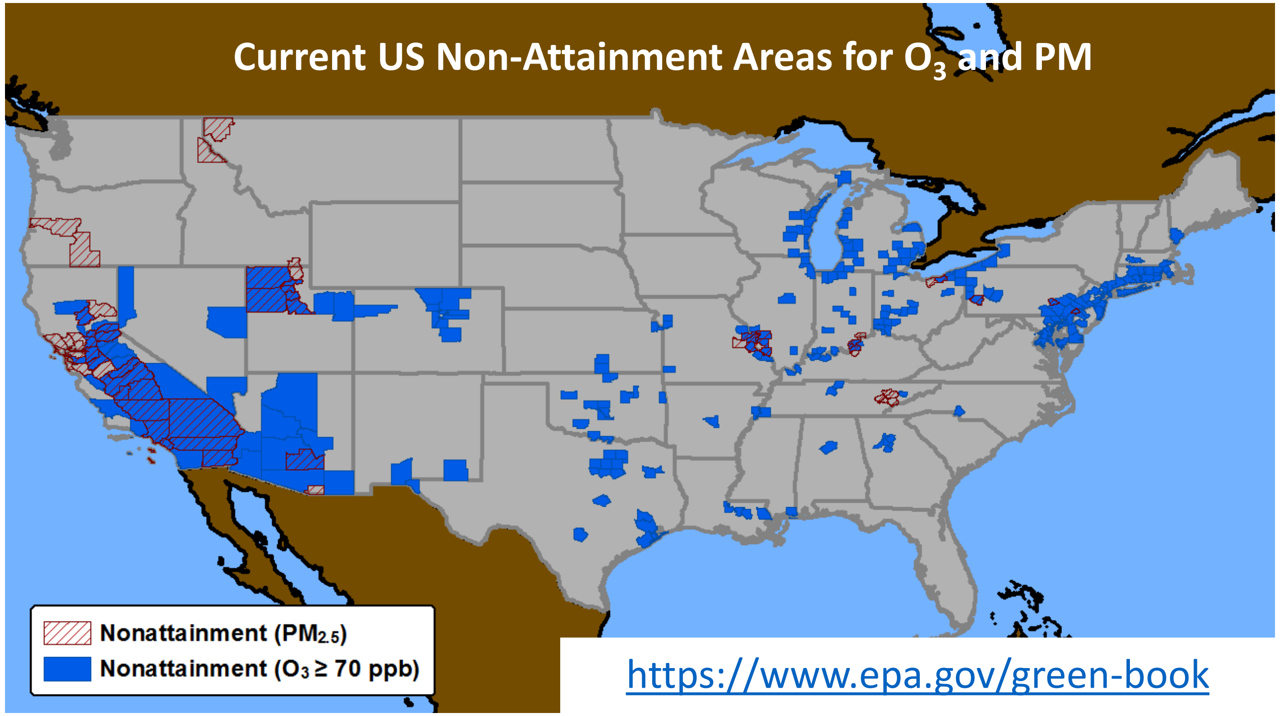


Figure 1. Changes in Concentrations of Criteria Pollutants, 1990–2015.





https://www.epa.gov/green-book

Poor air quality is an increasingly critical issue in many parts of the world and is a leading cause of global illness and mortality.


World Health Organization

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Public health, environmental and social determinants of health (PHE)

Burden of disease from ambient and household air pollution

In new estimates released, WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

Read the news release on air pollution attributable deaths

Read the feature story on air pollution

FAQs on air pollution and health
pdf, 169kb

Air pollution estimates
pdf, 1.16Mb
Summary of results and method descriptions

3.7 million deaths
attributable to ambient air pollution

4.3 million deaths
attributable to household air pollution

1600 cities
worldwide are reporting air pollution levels

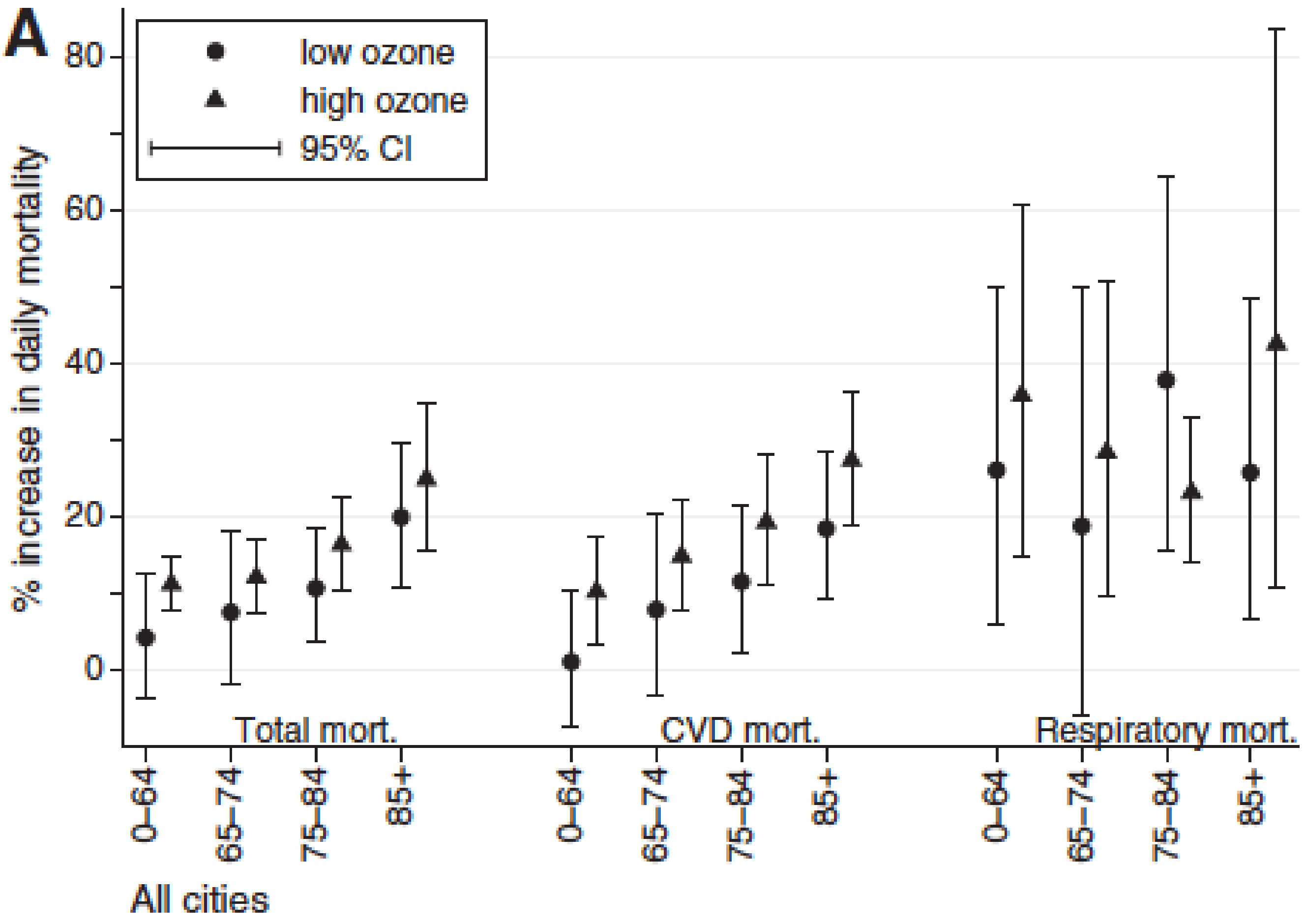
www.who.int/phe/health_topics/outdoorair/

"It was estimated in 2012 that 26% of childhood deaths and 25% of the total disease burden in children under five could be prevented through the reduction of environmental risks such as air pollution, unsafe water, sanitation and inadequate hygiene or chemicals."

World Health Organization

http://www.who.int/ceh/en/

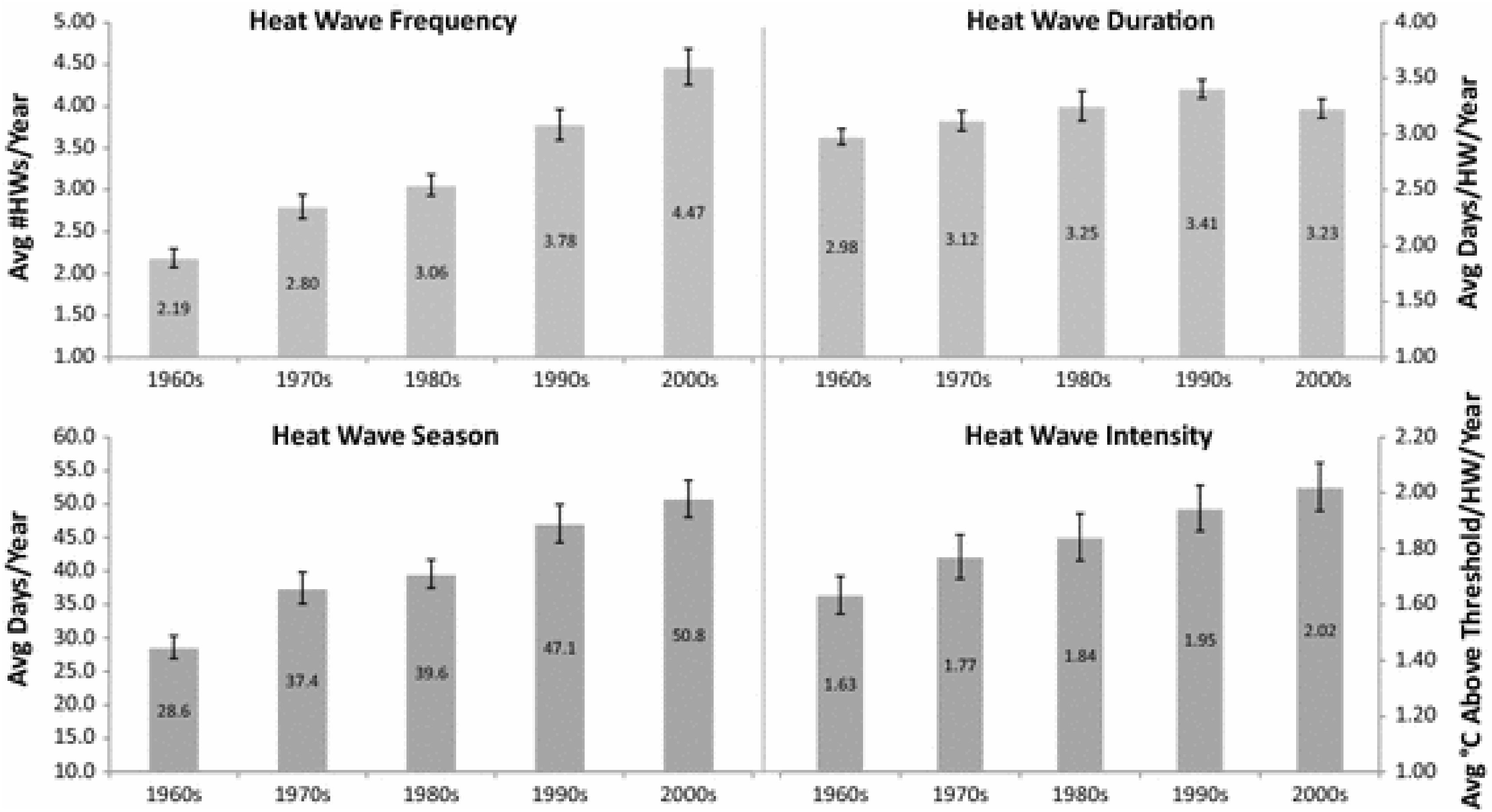
Poor air quality, particularly higher near-surface O_3, enhances human mortality on heat wave days compared with non-heat wave days, exacerbating the effect of increased temperatures alone.



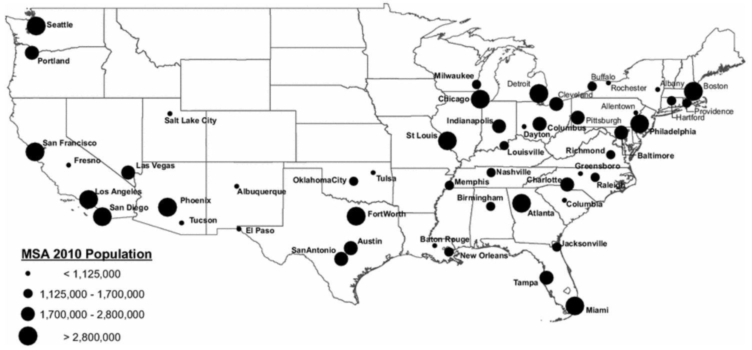
Results from a random effects meta-analysis in 9 European cities, showing % increase in the daily number of deaths in days with a heat wave and a "low" or "high" level of ozone, adjusting for barometric pressure, wind speed, calendar month, day of the week, holiday, and time trend, by cause of death and age group.

Analitis et al., Epidemiology, 2014

Observations from the past 50-60 years show that US heat waves are now more frequent, last longer, and are more intense.

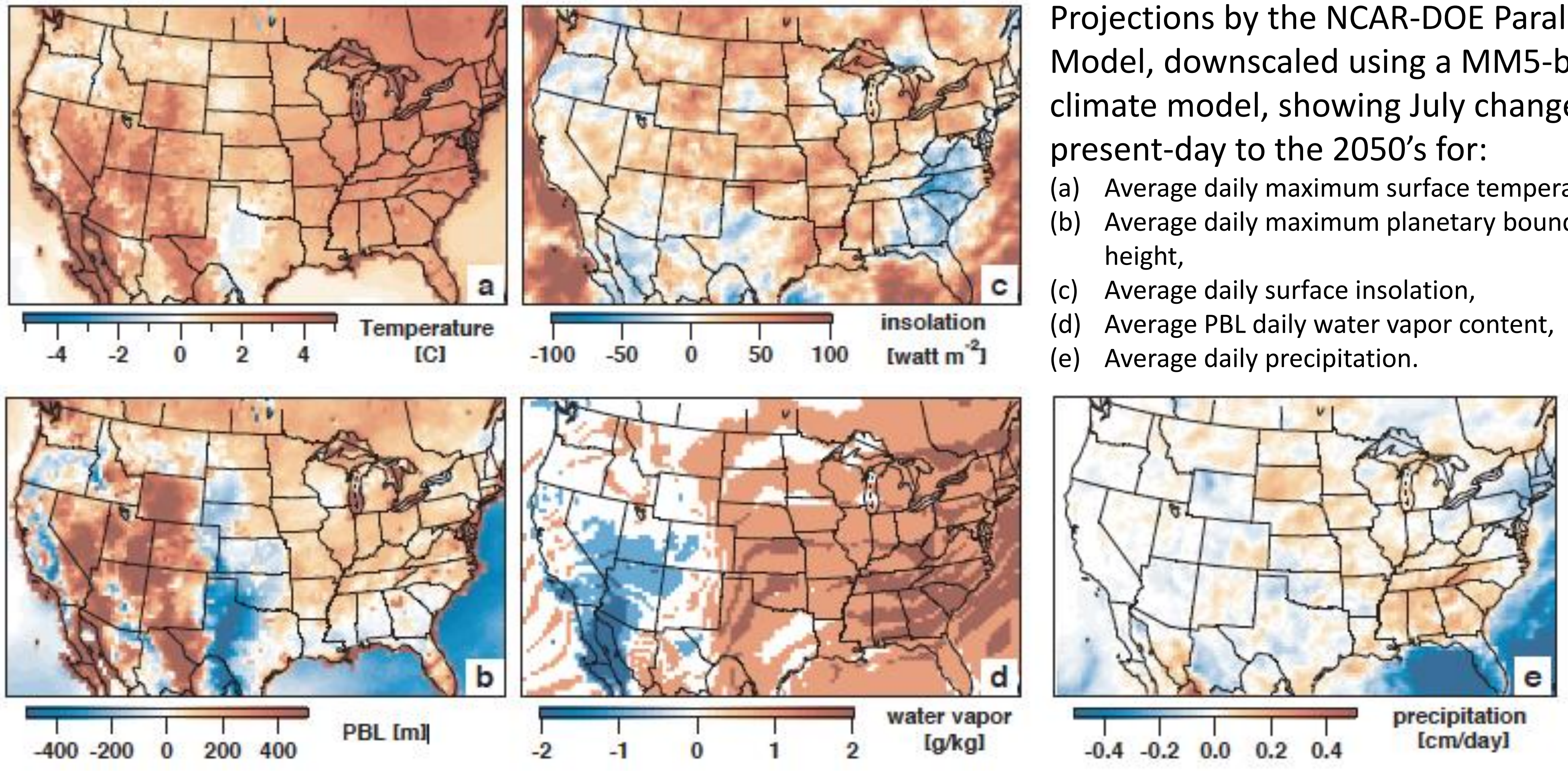


Decadal average for each heat wave characteristic across the 50 cities shown on the map below



Habbeb et al., Natural Hazards, 2015

Models predict substantial changes to typical summertime meteorology in the continental US within the next 30 years.



Projections by the NCAR-DOE Parallel Climate Model, downscaled using a MM5-based regional climate model, showing July changes from the present-day to the 2050's for:

(a) Average daily maximum surface temperature,
(b) Average daily maximum planetary boundary layer (PBL) height,
(c) Average daily surface insolation,
(d) Average PBL daily water vapor content,
(e) Average daily precipitation.

Avise et al., Atmos. Chem. Phys., 2009

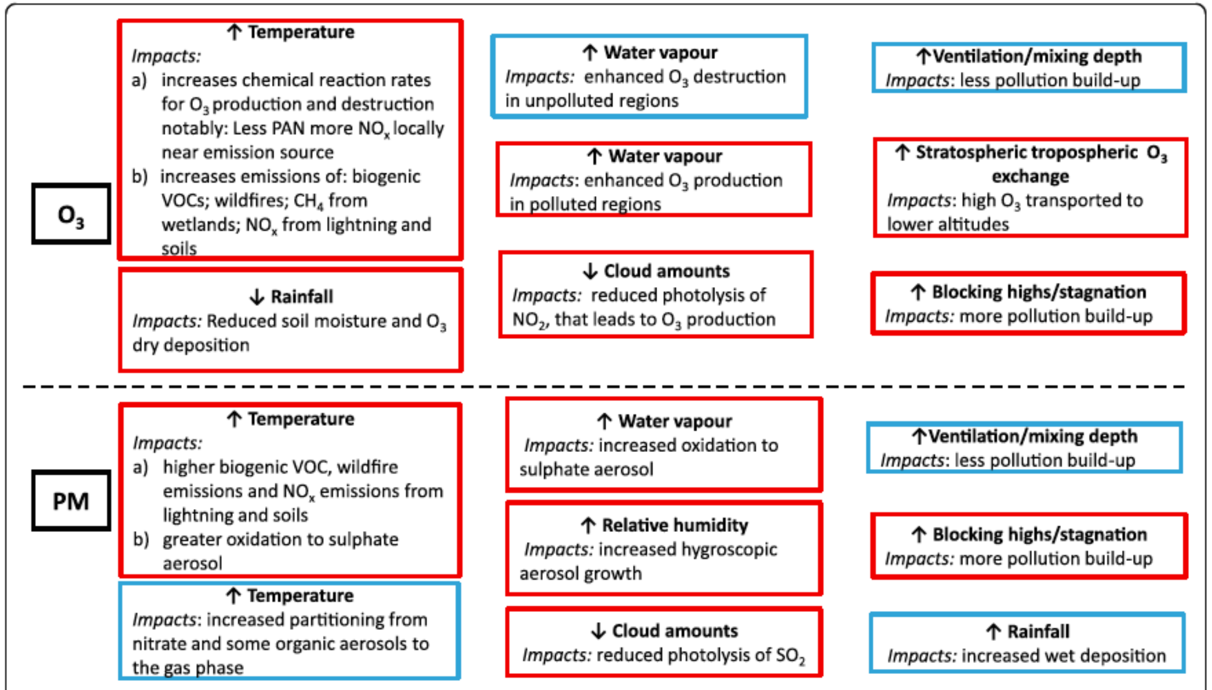
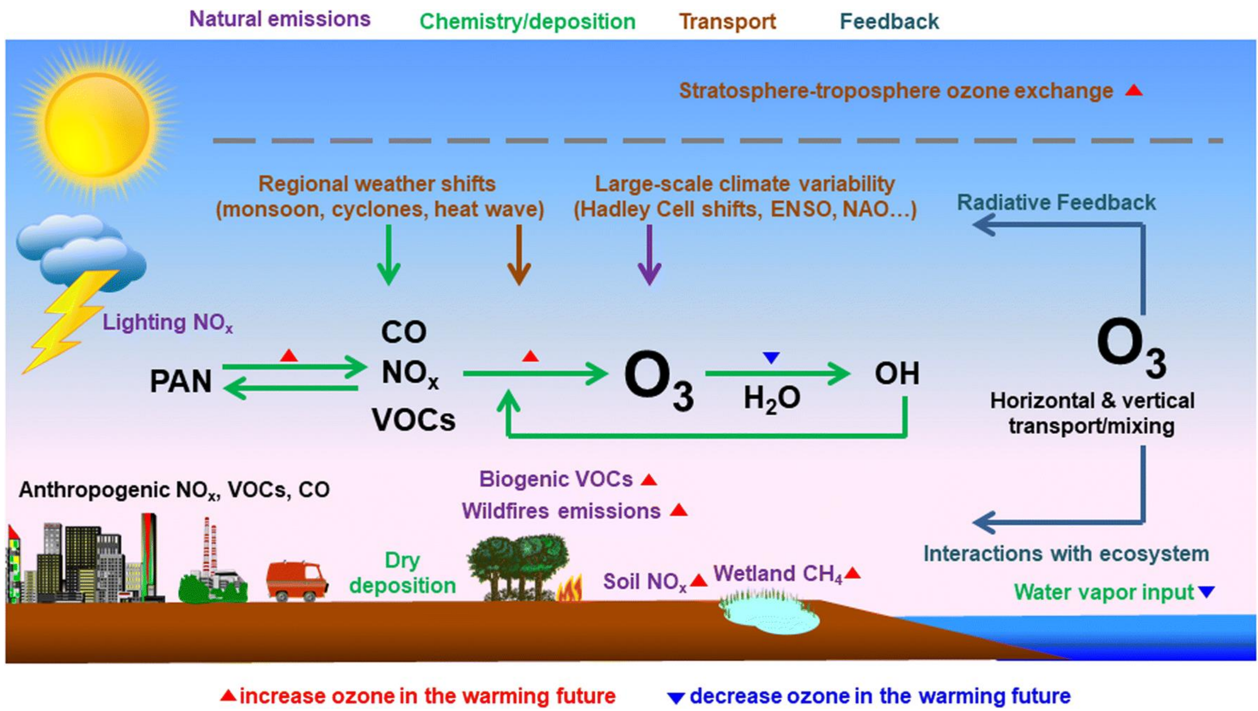


Fig. 1 The impacts of meteorological and climate variables on O_3 and PM concentrations as determined from studies in the literature. ↑ represents an increase in the variable and ↓ a decrease. A Red (blue) box outlines depict where changes in a given variable predict an increase (decrease) in O_3 or PM

Doherty et al., Environmental Health, 2017

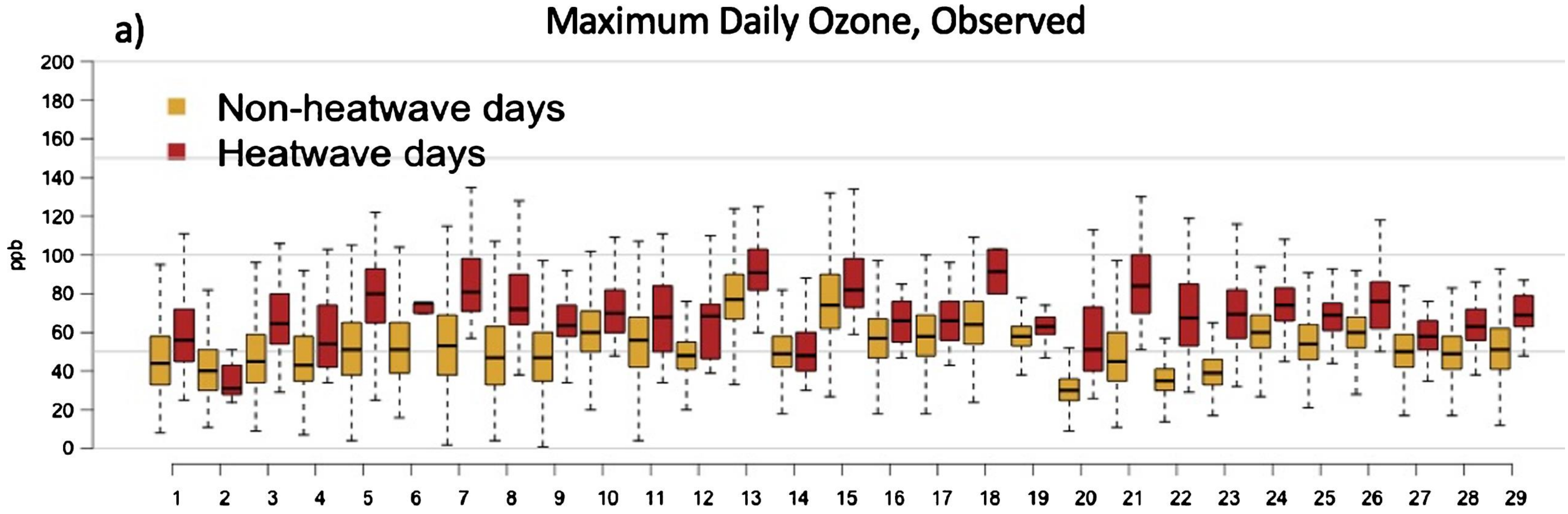
An extensive body of research demonstrates that near-surface O_3 and PM have complex responses to changes in meteorological variables.

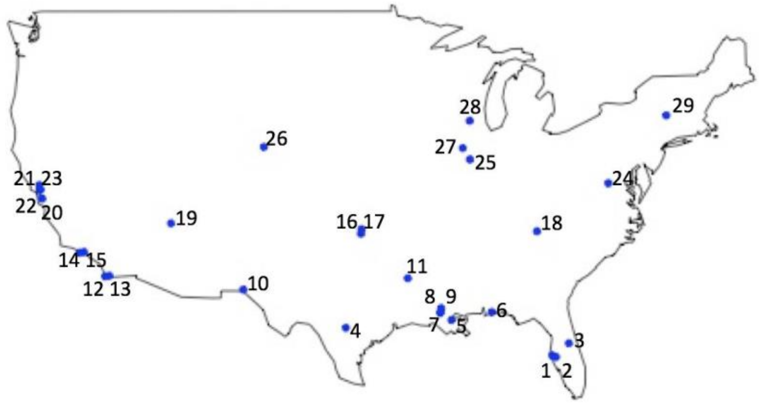
These responses in turn result from the myriad chemical reactions and their dependencies on temperature, sunlight, and precipitation, as well as on dynamical and physical processes.



Lu et al., Current Pollution Reports, 2019

Observations from the past few decades demonstrate that US air quality, at least in terms of ozone, is worse during heat waves.

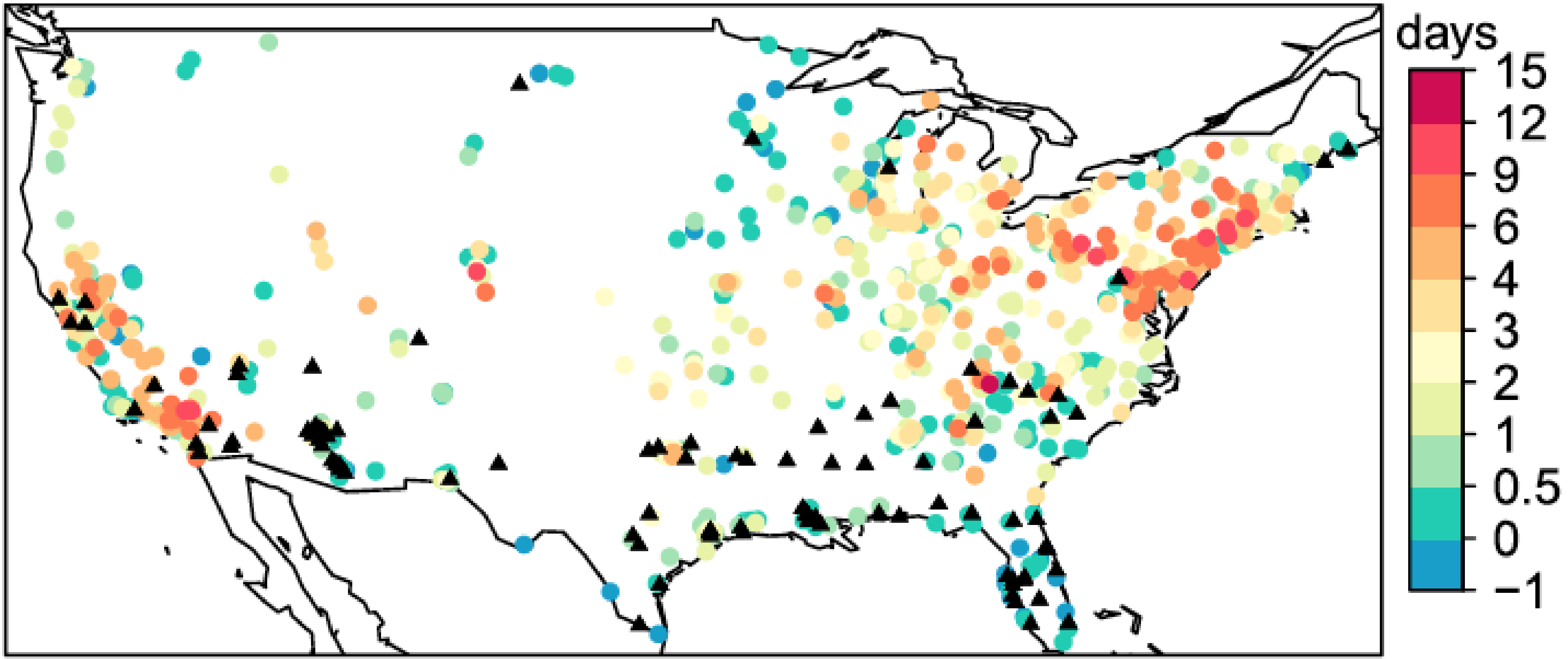




1990-2016 maximum daily observed during non-heat wave days (yellow) compared to heat wave days (red) for surface ozone concentration (ppb) for observations from the 29 sites across the US shown on the map at left.

Meehl et al., Geophys. Res. Lett., 2018

Models predict that by 2050, warmer temperatures will result in longer episodes of high ozone across much of the continental US, assuming anthropogenic precursor emissions remain constant.

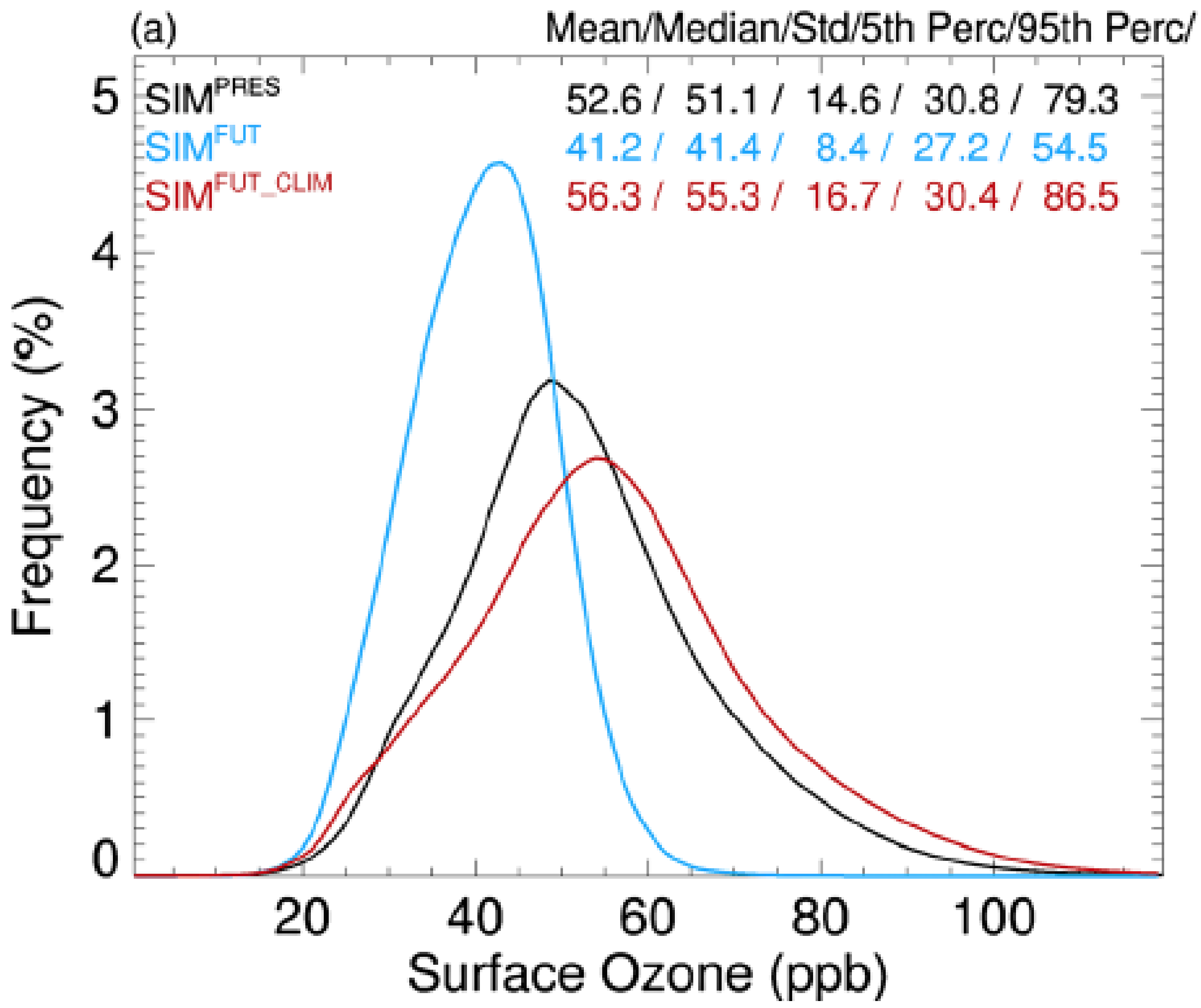


Mean changes from 2000–2009 to 2050–2059 in ozone episode days due to climate change in the RCP4.5 scenario, as calculated using statistically downscaled projections of daily maximum temperatures from 19 CMIP5 models sampled at 883 EPA AQS and CASTNet monitoring sites across the continental US.

Shen et al., Geophys. Res. Lett., 2016

Models predict that by mid-century, US surface ozone maxima will…

- decrease if anthropogenic O_3 precursor emissions decline,
- and increase if emissions remain at present-day levels.



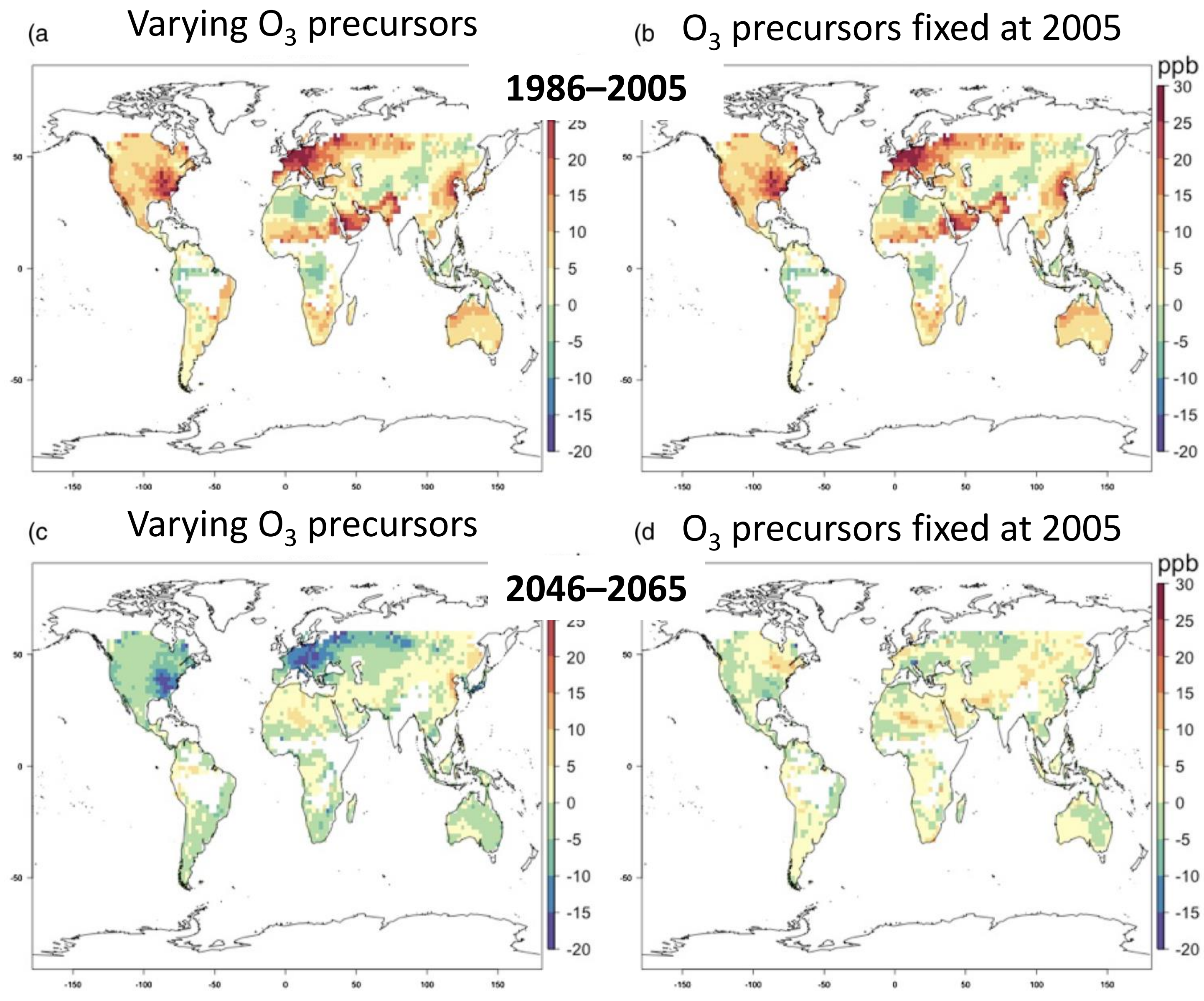
Frequency distribution of daily maximum 8 h surface ozone (ppb) over the contiguous US for JJA of all years for:

- Present (SIM^{PRES})
- Future with reduced anthropogenic emissions (SIM^{FUT})
- Future with present-day anthrop emissions (SIM^{FUT_CLIM})

Mean, median, standard deviation, and 5th and 95th percentiles are shown for each simulation type

	SIM^{PRES}	SIM^{FUT}	SIM^{FUT_CLIM}
Years	1996–2008	2046–2058	2046–2058
Climate	1996–2008	2046–2058	2046–2058
Anth. emis.	Present (2000)	Future (RCP 8.5 2050)	Present (2000)
Chem. IC/BC	2000	2050	2050
Methane	1.8 ppm	2.8 ppm	2.8 ppm

Pfister et al., Geophys. Res. Lett., 2014



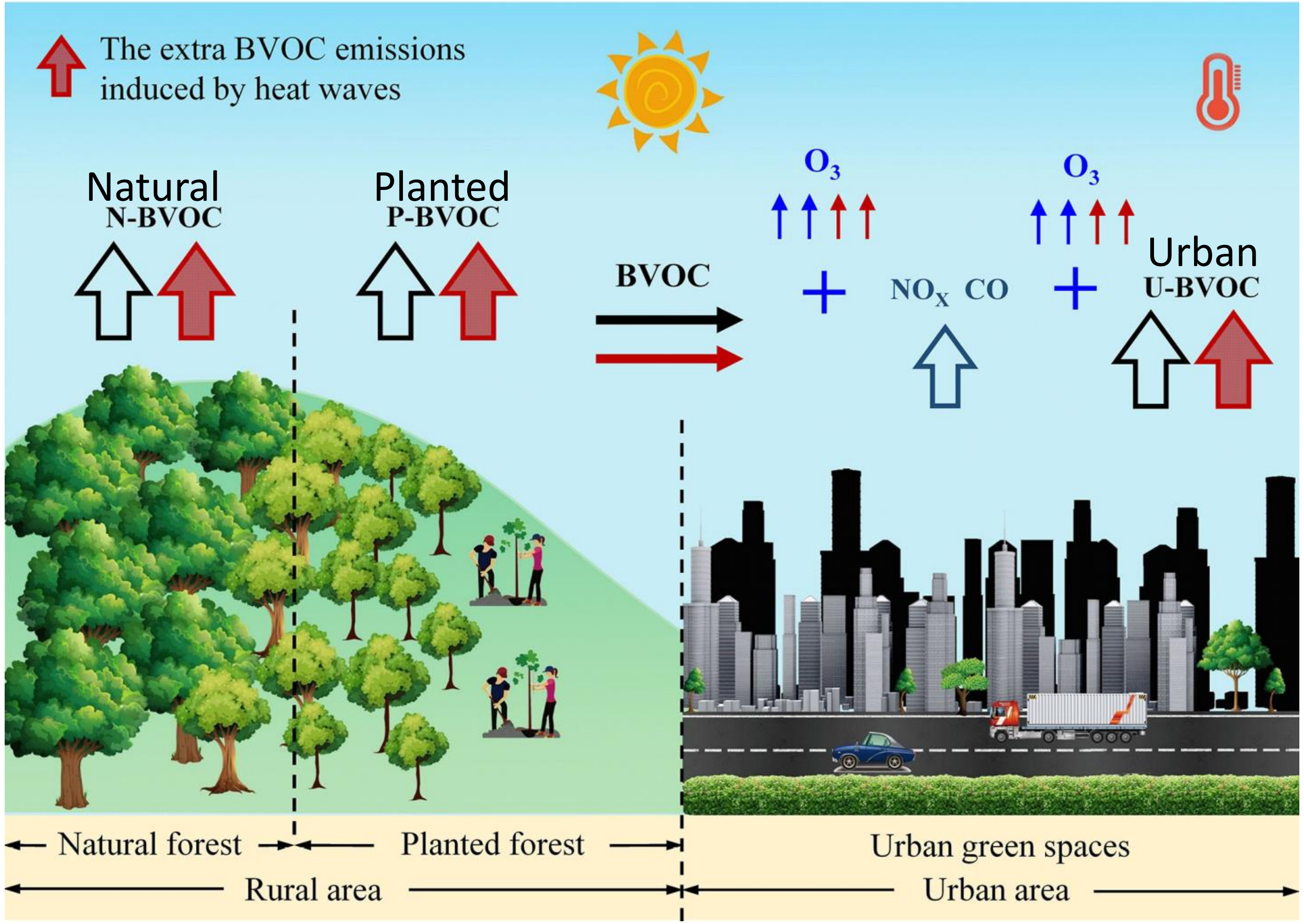
Difference in surface ozone concentration (ppb) predicted by NCAR Community Earth System Model v1 for (heat wave days - non-heat wave days)

Models predict that by the mid-21st century:

- Where precursor emissions decrease, O_3 will decrease more on heat wave days than non-heat wave days.
- O_3 will increase where precursor emissions are constant or increasing.
- Biogenic emissions changes from higher temperatures will modulate the impacts of anthropogenic emissions changes.

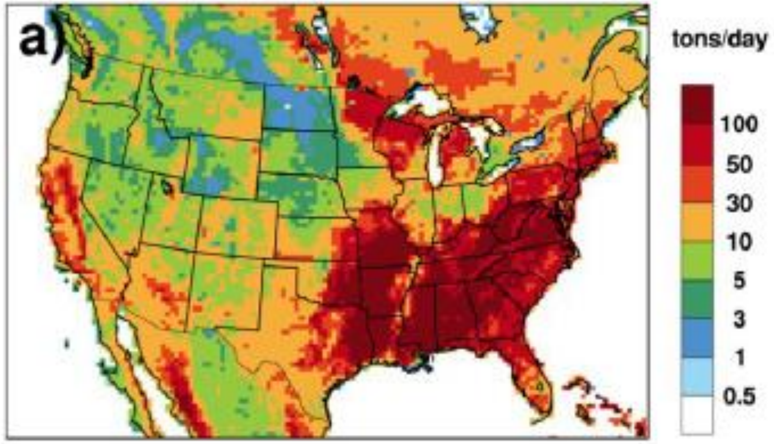
Meehl et al., Geophys. Res. Lett., 2018

Heat waves will increase biogenic emissions from both natural vegetation and managed landscapes, providing more O_3 and PM precursors regardless of how anthropogenic emissions change.

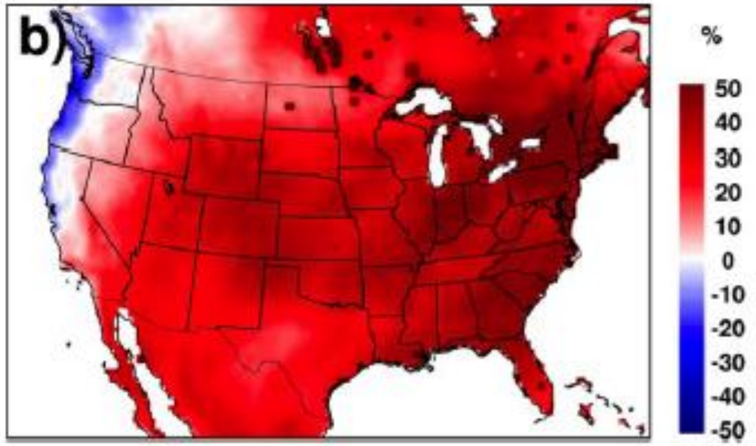


Ma et al., Atmos. Chem. Phys., 2019

Current decade summer E(isoprene)



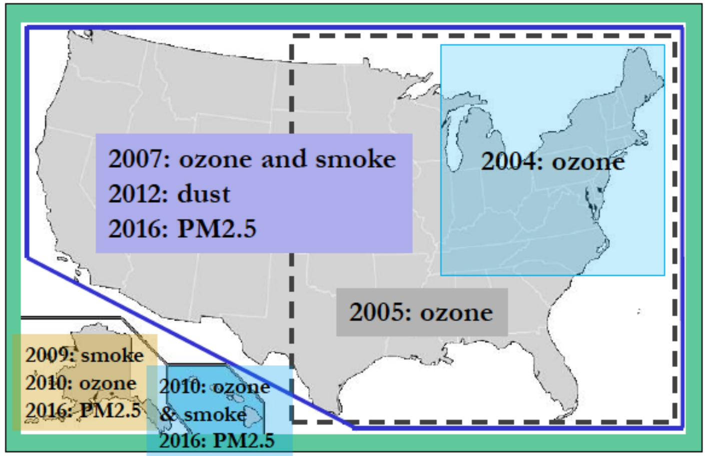
% change in future summer E(isoprene)

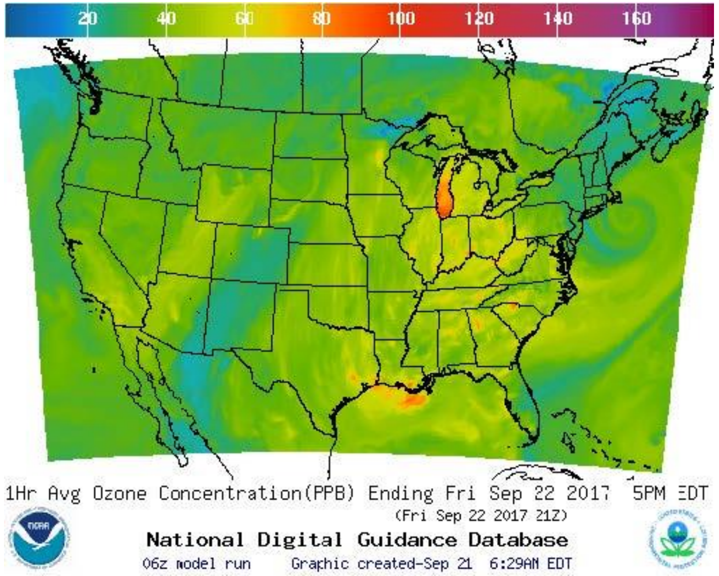


Gonzalez-Abraham et al., Atmos. Chem. Phys., 2015

NOAA is mandated to produce an operational National Air Quality Forecast Capability, which requires ongoing research for improvement.

	AQ Alerts Prior to NAQFC	Current NOAA's Operational Capability (2016)
Purpose - Limit adverse effects from poor AQ, by providing:	Next-day warnings for large cities	State-of-the-science ozone, smoke, dust and fine particulate matter (PM2.5) forecast guidance
Products for Public	Daily AQ alerts; predicted interpretive AQ Index category	Hour-by-hour predictions of ozone, smoke, dust and PM2.5 concentrations in digital & graphical formats
Coverage	More than 300 cities	Nationwide for ozone, smoke and PM2.5, CONUS for dust
Pollutants Forecasted	AQ Index for ozone; some cities include particulate matter	Ground-level ozone, dust, smoke and PM2.5
Forecast Period	Next-day; also through weekends	Forecast guidance through midnight next day
Spatial Resolution	Alerts are community-wide; little/ no other spatial information	12 kilometer grid
Temporal Resolution	Daily	1-hr averages each hour for ozone, smoke, and dust 8-hr averages each hour for ozone





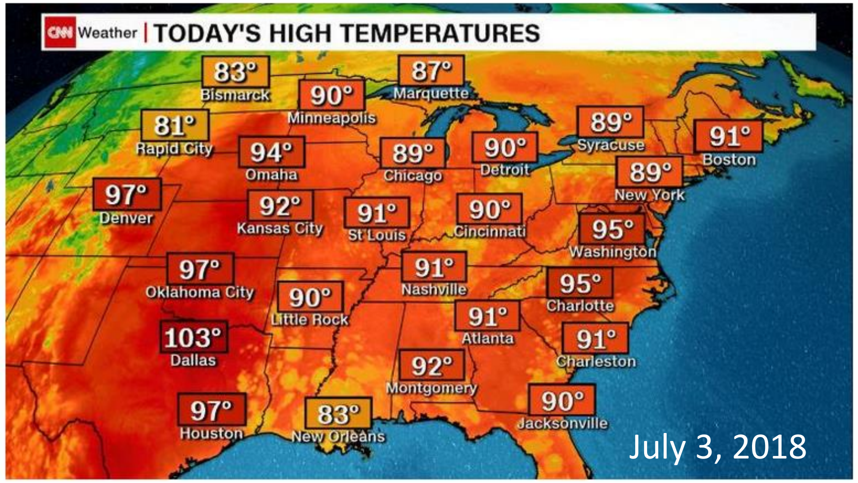
https://airquality.weather.gov/

https://www.weather.gov/sti/stimodeling_airquality

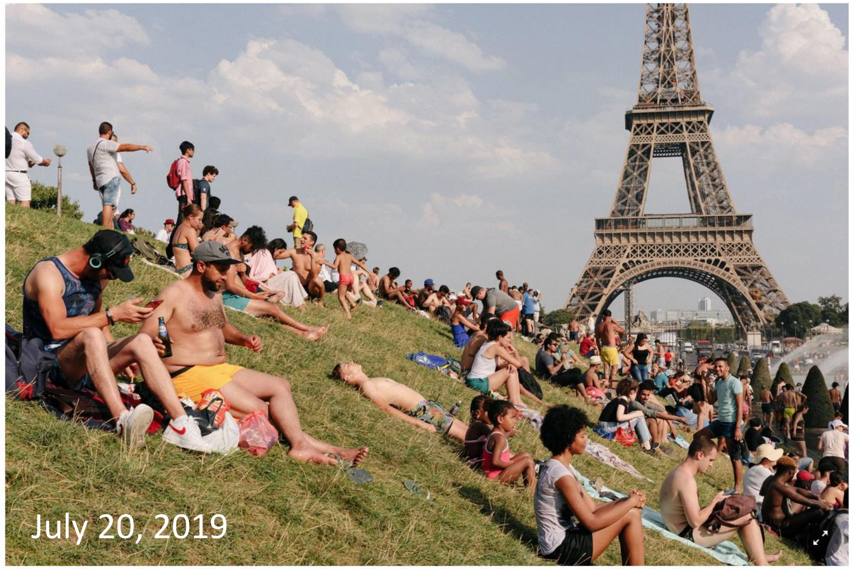
https://www.arl.noaa.gov/research/atmospheric-chemistry/ozonepm-forecast-products/

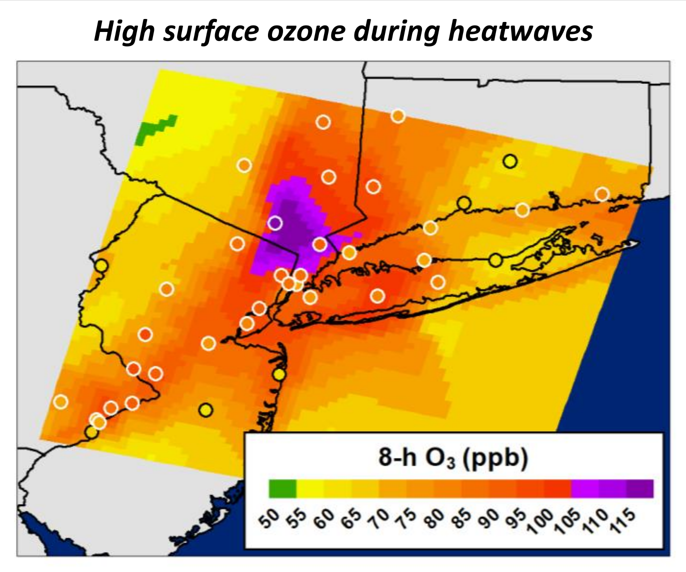
NOAA has a powerful research toolbox to study urban air quality during heat waves.

CNN — Heat wave turns deadly and is expected to last through the Fourth of July



The New York Times — *A Heat Wave Bakes Europe, Where Air-Conditioning Is Scarce*

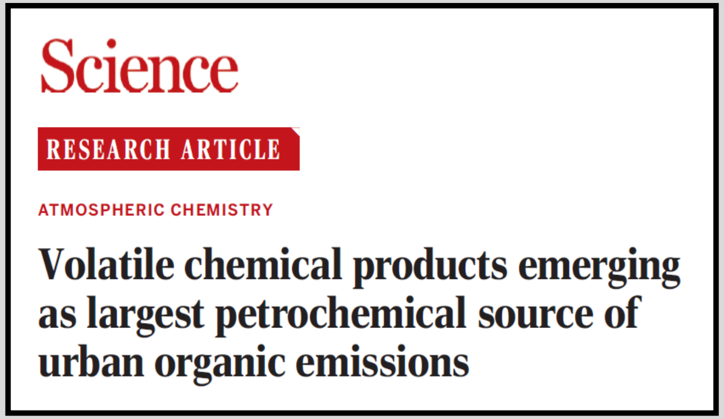




Weather-Chemistry Models

Mobile Laboratories

Aircraft Measurements


Science

RESEARCH ARTICLE

ATMOSPHERIC CHEMISTRY

Volatile chemical products emerging as largest petrochemical source of urban organic emissions

New Insights into Emissions

Some concluding thoughts

- Anthropogenically-induced climate change is increasing the frequency and duration of extreme heat events.
- In addition to its meteorological impacts, extreme heat generally increases biogenic and anthropogenic emissions and the rate of atmospheric chemical reactions, leading to a complex set of responses by near-surface O_3 and PM.
- Extreme heat generally causes poorer air quality, with attendant adverse impacts on human health.
- Air quality impacts from extreme heat, including the frequency and duration of high ozone events, will already be significant by the mid-21st century.
- NOAA's mission to protect lives and property provides the mandate to maintain and improve its capabilities to measure, understand, and make projections of how extreme heat affects air quality.
- CPO/ESSM can help lead these efforts, by convening the expert community, supporting research, and communicating science to stakeholders.